

# Homework 1

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## 1 Page 8: problem 10

An annuity increases each month by an automatic deposit of 1% interest on the previous month's balance. Your grandparents withdraw \$1000 at the beginning of each month for living expenses. Currently, they have \$50,000 in the annuity. Model the annuity with a dynamic system.

$$\begin{aligned}\Delta b_n &= \Delta b_{n+1} - b_n = .01b_n - 1,000 \\ b_{n+1} &= b_n + .01b_n - 1,000 \\ b_o &= 50,000\end{aligned}$$

Will the annuity run out of money?

```
a_n <- original_amount <- 50000
x <- 1000
count <- 0

while (1.01*a_n > 1000){
  a_n <- a_n + (.01 * a_n) - x
  count <- count + 1
  if (a_n >= original_amount){
    print("the annuity will not run out")
    break
  }
}
```

Yes, the code above runs without indicating that the annuity will not run out. This is because our initial amount is decreasing with each sequence so it has a termination point.

When? The annuity will run out at 69 months.

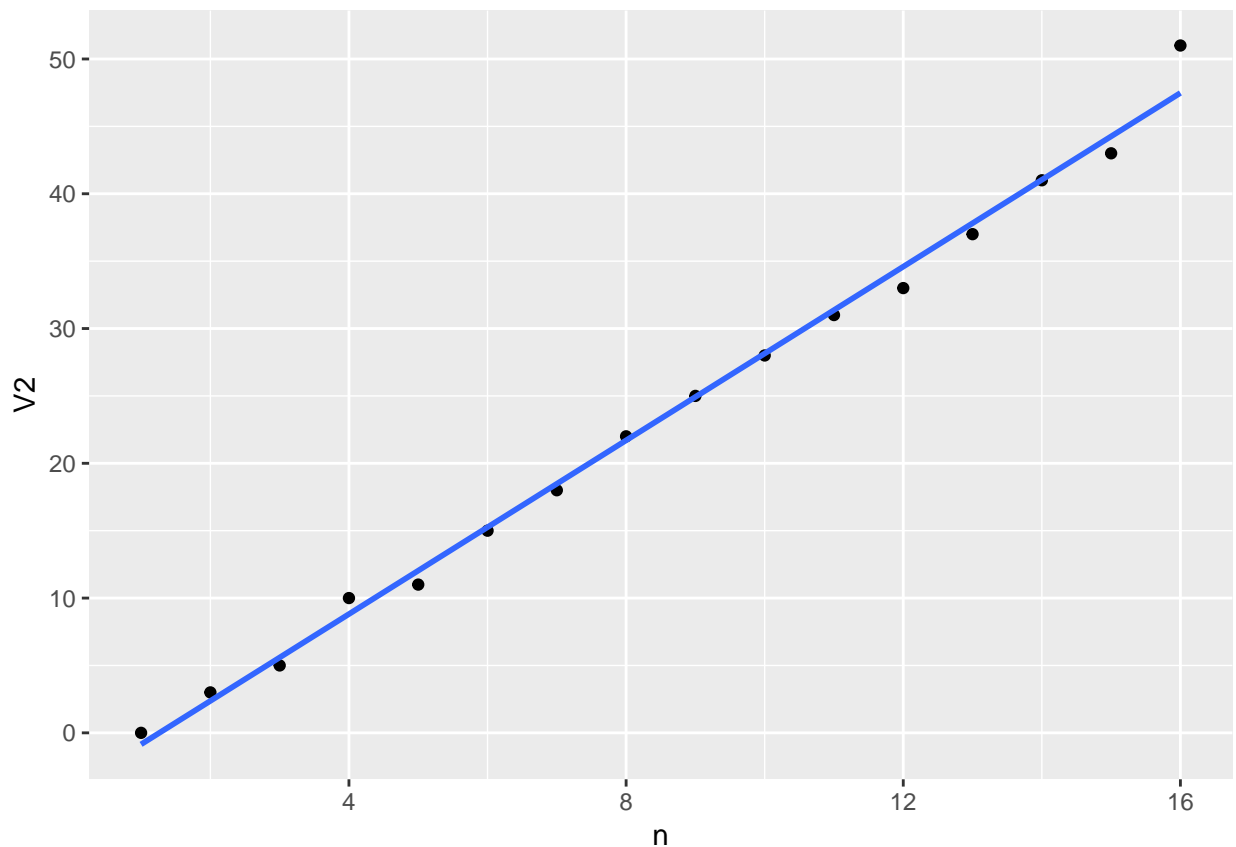
## 2 Page 17: problem 9

The data in the accompanying table show the speed  $n$  (in increments of 5 mph) of an automobile and the associate distance  $a_n$  in feet required to stop it once the breaks are applied. For instance,  $n = 6$  (representing  $6 \times 5 = 30$  mph) requires a stopping distance of  $a_6 = 47$ ft.

- a. Calculate and plot the change  $\Delta a_n$  versus  $n$ . Does the graph reasonably approximate a linear relationship?

The graph of  $\Delta a_n$  does approximate a linear relationship.

```
library(ggplot2)
n <- c(1:16)
a_n <- c(3, 6, 11, 21, 32, 47, 65, 87, 112, 140, 171, 204, 241, 282, 325, 376)
ggplot(data = as.data.frame(cbind(n, c(0, diff(a_n)))), aes(x = n, y = V2)) +
  geom_point() +
  geom_smooth(method = "lm", se = FALSE)
```



- b. Based on your conclusion in part(a), find a difference equation model for the stopping distance data. Test your model by plotting the errors in the predicted values against  $n$ . Discuss the appropriateness of the model.

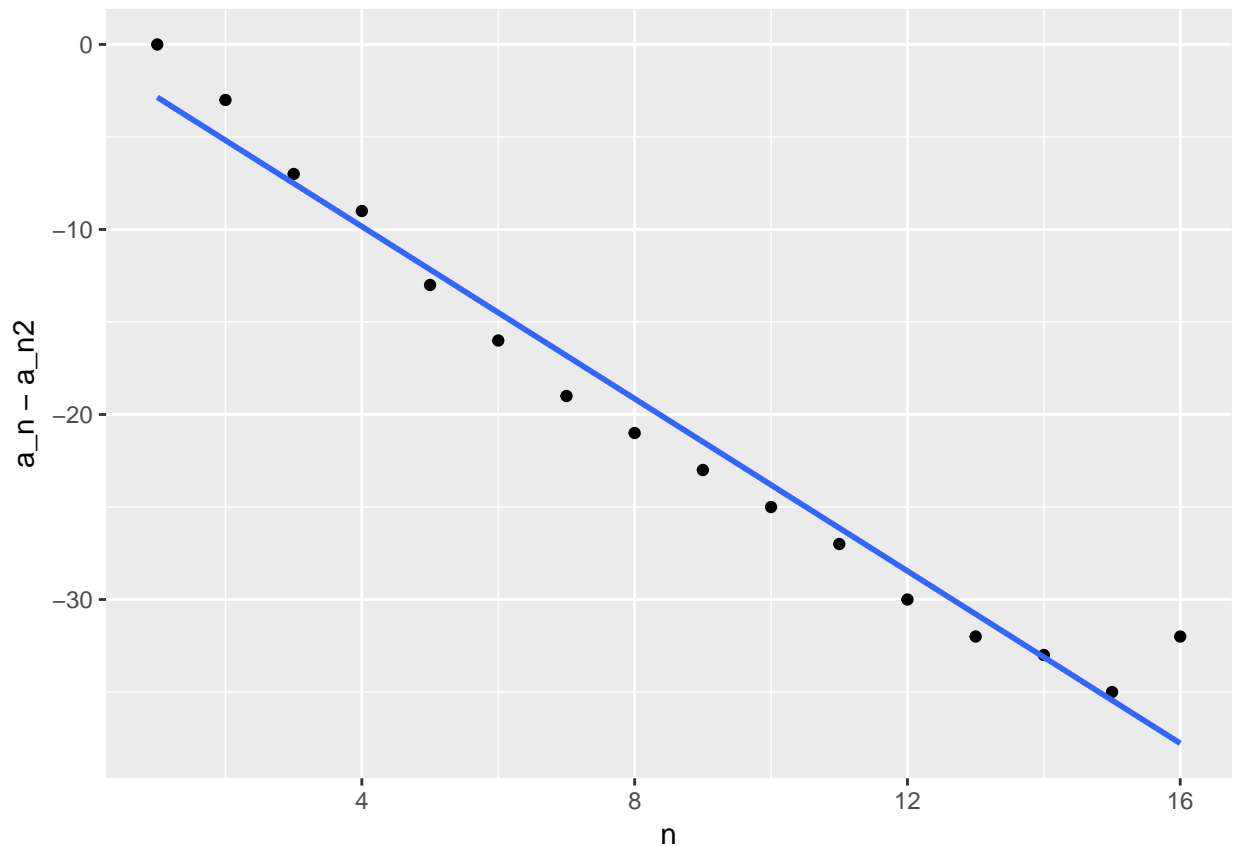
The plotting of errors shows a linear relationship which will only grow over time. Therefore, this model is not appropriate.

$$a_{n+1} = 3n + a_n$$

```
df <- as.data.frame(cbind(n, a_n, diff = c(0, diff(a_n))))

for (i in 1:length(a_n)){
  if (i == 1){
    df$a_n2[[i]] <- a_n[[i]]
  } else {
    df$a_n2[[i]] <- (df$n[[i]] *(df$diff[2] - df$diff[1]) + df$a_n2[[i-1]])
  }
}

ggplot(data = df, aes(x = n, y = a_n - a_n2)) +
  geom_point() +
  geom_smooth(method = "lm", se = FALSE)
```



## Page 34: #13

## 2.1 TODO finish question

Considering the spreading of a rumor through a company of 1000 employees, all working in the same building. We assume that the spreading of a rumor is similar to the spreading of a contagious disease in that the number of people hearing the rumor each day is proportional to the product of the number who have heard the rumor previously and the number who have not heard the rumor. This is given by

$$r_{n+1} = r_n + kr_n(1000 - r_n)$$

where  $k$  is a parameter that depends on how fast the rumor spreads and  $n$  is the number of days. Assume  $k = 0.001$  and further assume that four people initially have heard the rumor. How soon will all 1000 employees have heard the rumor?

## 2.2 Page 55: #6

## 2.3 TODO finish question

An economist is interested in the variation of the price of a single product. It is observed that a high price for the product in the market attracts more suppliers. However, increasing the quantity of the product supplied tends to drive the price down. Over time, there is an interaction between price and supply. The economist has proposed the following model, where  $P_n$  represents the price of the product at year  $n$ , and  $Q_n$  represents quantity. Find the equilibrium values for the system.

$$P_{n+1} = P_n - 0.1(Q_n - 500)$$

$$Q_{n+1} = Q_n + 0.2(P_n - 100)$$

- Does the model make sense intuitively? What is the significance of the constants 100 and 500? Explain the significance of the signs of the constants -0.1 and 0.2.
- Test the initial conditions in the following table and predict the long-term behavior

```
library(knitr)
price <- c(100, 200, 100, 100)
quantity <- c(500, 500, 600, 400)
row_names <- c("Case A", "Case B", "Case C", "Case D")
x <- as.data.frame(cbind(price, quantity))
row.names(x) <- row_names
kable(x)
```

	price	quantity
Case A	100	500
Case B	200	500
Case C	100	600
Case D	100	400